A New Quasi-Optimum Power Control Scheme for Downlink in W-CDMA Macro Cellular System

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Abstract. *The downlink power control problem in W-CDMA is studied using a new proposed model. The downlink cell capacity is given for the old model given by Gejji and our new model. A capacity increase of 16 % for the special case $\phi = 0$ (no orthogonality between users) and a generalization of the old model in terms of the propagation exponent and orthogonality factor is introduced.*

Keywords

Downlink capacity, power control, W-CDMA.

1. Introduction

The downlink power control problem in W-CDMA (Wideband Code Division Multiple System) is considered. This problem has been identified by Lee [1], and Gilhousen et al [2] as an important issue of the capacity of the CDMA cellular system. The purpose of the downlink power control is to reduce the amount of the interference from the neighboring cells by reducing the total amount of power transmitted by the base station [3]. In the downlink power allocation and user capacity for the 3GPP (3rd Generation Partnership Project) system, the power reduction factor is taken as 0.5 extracted from the old work of Lee [4]. Since power control consists of reducing the share of power transmitted for the close-in users, it is possible that a power control law devised on the bases of the CIR (Carrier to Interference Ratio) of boundary users could put the close-in users in a disadvantage. A service hole can exists if the power control strategy is based on the need of the boundary users and the very close-in users. Thus the power control law should prevent the occurrence of service hole in the internal of the cell. When the power control is used in the downlink, the downlink capacity increases. The aim of this work is to give more accurate values of the power reduction factor for different values of the power reduction factor for different values of the orthogonality factor and the propagation exponent.

2. Power Control Model

We use the geometry depicted in Fig. 1 to calculate the intracellular and intercellular interference from 19 cells of radius R. We assume that the user i is located along the line AB within the cell 1 and at a distance r from its base station. Using the old model [3], the transmitted power for a user at distance r from the base station is given as

$$P_t(r) = P_R f(r) \tag{1}$$

where P_R is the reference power level corresponding to the signal power transmitted for a user located at $r = R$, and

$$f_{old}(r) = \begin{cases} \left(\dfrac{r_o}{R}\right)^n & for \quad r \le r_o, \\ \left(\dfrac{r}{R}\right)^n & for \quad r > r_o. \end{cases} \tag{2}$$

$P_t(r)$ is assumed to be proportional to the user distance raised to n, but every user located at a distance less than r_0 is assured of a minimum amount of transmitted power.

For analytical convenience, hexagonal cells are approximated by circular cells with radius R [5]. Assuming a uniform distribution of N users within the cell, the users density ρ is

$$\rho = \frac{N}{\pi R^2} \tag{3}$$

The total power transmitted by the base station is

$$P_{T\,old} = \frac{NP_R}{\pi R^2} \int_0^{2\pi} \int_0^R f(r) r dr d\theta \tag{4}$$

$$= \frac{2N\pi P_R}{\pi R^2} \int_0^R f(r) r dr = NP_R \kappa_{old} \tag{5}$$

being

$$\kappa_{old} = \frac{2}{n+2} + \frac{n}{n+2}\left(\frac{r_o}{R}\right)^{n+2} \tag{6}$$

and κ_{old} is the power control reduction factor of the old model which has a value of 0.5 to 0.6 [4]. The drawback of the model of Gejji (The Old Model) is that the power assigned to the users near to the cell center is more than the real need especially when users orthogonality exists. To solve this drawback we propose a new model in which the power assigned to the users near the center of the cell is reduced according to the system situation.

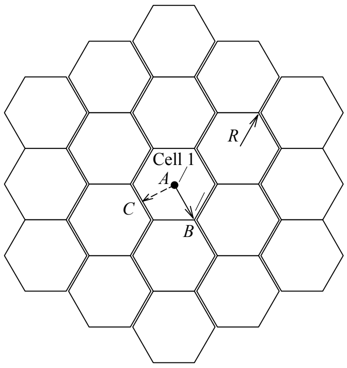

Fig. 1. The 19 macro-cells model.

The power profile of our new model is given by

$$f_{new}(r) = \sum_{m=0}^{M} a_m \left(\frac{r}{R}\right)^m . \tag{7}$$

The total transmitted power factor ($P_{T\,new}$) is given as

$$P_{T\,new} = NP_R \kappa_{new} \tag{8}$$

where

$$\kappa_{new} = 2\sum_{m=0}^{M} \frac{a_m}{m+2} . \tag{9}$$

The factors $a_0,\ldots, a_M$ are found from the curve fitting of the interference profile. In our analysis we use $M = 5$.

3. Downlink Capacity

For the downlink, the ratio (E_b/N_0) at distance r from the home cell base station is given by

$$\frac{E_b}{N_o} = \frac{P_{ch}.f(r).G_p}{\alpha.\gamma(r).N(r).\kappa} \tag{10}$$

where P_{ch} is the power assignment for the users channels ≈ ≈ 0.8, G_p is the W-CDMA processing gain, α is the source activity factor, $N(r)$ is the users profile and $\gamma(r)$ is the downlink interference factor given by

$$\gamma(r) = (1-\phi) + \sum_{j=2}^{J}\left(\frac{r}{R_{ij}}\right)^s \tag{11}$$

and ϕ is the orthogonality factor, R_{ij} is the distance between the user i and the base station j, and s is the propagation loss exponent. For $s = 4$, the factor $\gamma(r)$ increases from $(1-\phi)$ at $r = 0$ to $(3.36-\phi)$ at $r = R$ when the user is located along the line AB.

Then, the users profile $N(r)$ at a distance r is given by

$$N(r) = \frac{P_{ch}.f(r).G_p}{\alpha.\gamma(r).(E_b/N_o)_{req}.\kappa} \tag{12}$$

where $(E_b/N_0)_{req}$ is the (E_b/N_0) ratio required to get a given bit error rate.

The downlink capacity (Cap_d) is given as

$$Cap_d = \min\left[N(r)\right]. \tag{13}$$

4. Numerical Results

We assume the following for the voice service:

- $G_p = 400$
- $(E_b/N_0)_{req} = 5$ dB
- $\alpha = 0.5$ (voice users)

The old model assumes that the orthogonality factor $\phi = 0$ and $s = 4$, therefore we will examine this case. In [3], [5], the best result is obtained when $n = 2$, $r_0 = 0.6\,R$. Fig. 2 shows the capacity profile for the old model when n is 2, $r_0 = 0.6\,R$. From Fig. 2, the capacity using the old model is 106 voice users/sector. The power reduction factor (κ_{old}) is 0.565.

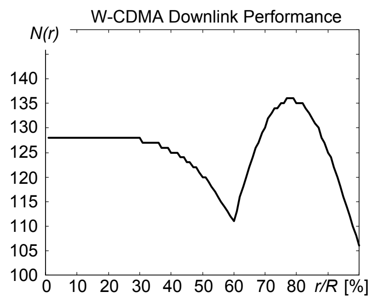

Fig. 2. The downlink sector capacity using the old model, $\phi = 0$, $r_0 = 0.6\,R$, $n = 2$ for voice users.

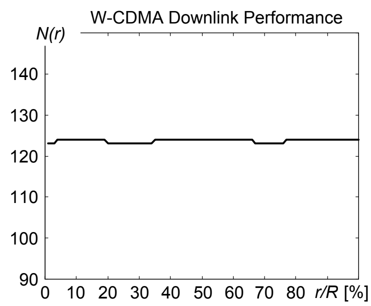

Fig. 3. The downlink sector capacity using the new model, $\phi = 0$ for voice users

Then we consider the case of our new model when $\phi = 0$. Fig. 3 shows the capacity profile of the downlink for this case. The capacity using the new model is 123 voice users per sector. The power reduction factor (κ_{new}) is 0.485. This model gives a downlink capacity increase of about 16%.

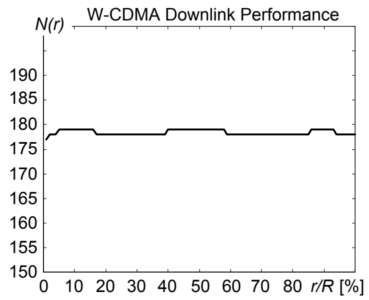

Fig. 4. The downlink sector capacity using the new model, $\phi =$ $= 0.5$ for voice users

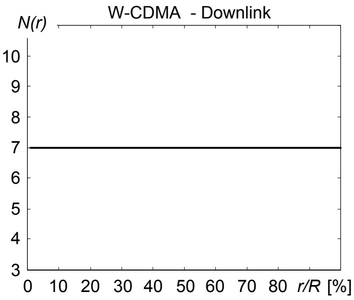

Fig. 5. The downlink sector capacity using the new model, $\phi = 0$ for data users.

Next we consider the case when ϕ = 0.5. Fig. 4 shows the capacity profile of the downlink for the new model. The capacity using the new model is 177 voice users/sector. The power reduction factor (κ_{new}) is 0.395.

Next we assume the following for the data service [6]:

- $G_p = 26.66$
- $(E_b/N_0)_{req} = 2.7$ dB
- $\alpha = 1$ (data users)

Fig. 5 shows the capacity profile of the downlink for the case $\phi = 0$. The capacity using the new model is 7 data users/sector.

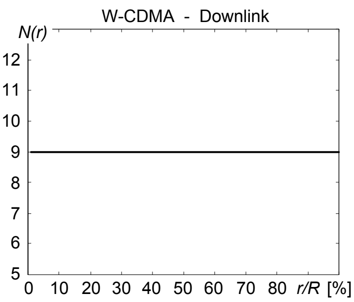

Fig. 6. The downlink sector capacity using the new model, $\phi =$ $= 0.5$ for data users.

Fig. 6 shows the capacity profile of the downlink for the case $\phi = 0.5$. The capacity using the new model is 9 data users/sector.

Table 1 gives the value of κ_{new} for different values of ϕ and s. For ϕ = 0.5 the value of κ_{new} is always less than 0.42. It worth mentioning that, in the macrocellular environment the exponent s has a value of (3.5 to 4) and ϕ ≈ 0.5 [7].

Case	s	ϕ	κ_{new}
1	3.50	0.0	0.497
2	3.50	0.5	0.414
3	3.75	0.0	0.490
4	3.75	0.5	0.404
5	4.00	0.0	0.485
6	4.00	0.5	0.395

Tab. 1. The value of κ_{new} for different values of s and ϕ.

5. Remarks

- The capacity profile in other directions (AC for example) can be get using the same methodology.
- The more flat the users capacity profile is, the better power control scheme is obtained.
- In the WCDMA system, a portion of about 0.15 % of the total transmitted power is assigned to the pilot signal. Therefore the sector capacity is 85 % of the above mentioned capacities.
- If a cell with 3 sectors is used, the downlink capacity will be (2.4 to 2.5) times higher, i.e., Cell capacity $\approx$ (2.4-2.5) × sector capacity.

6. Conclusion

A new model for the W-CDMA downlink power control is proposed and the downlink cell capacity is compared for the old and new models. A 16 % increase in the cell capacity is obtained using the new model for the case of non-orthogonal users. The new model generalizes the old one. It is worth mentioning that our new model is quasi-optimum power control model, i.e., it gives a flat or a quasi flat capacity profile.

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